R E P O R T R E S U M E S

ED 002 887 24

EFFECTS AND INTERACTIONS OF AUDITORY AND VISUAL CUES IN ORAL COMMUNICATION.

BY- KEYS, JOHN W. AND OTHERS
OKLAHOMA UNIV., NORMAN, RESEARCH INSTITUTION

REPORT NUMBER CRP-499 PUB DATE 60
CONTRACT OEC-SAE-8277
EDRS PRICE MF-$0.09 HC-$1.48 37P.

DESCRIPTORS- *ORAL COMMUNICATION, AUDIOVISUAL AIDS, *AUDITORY DISCRIMINATION, *LIPREADING, SPEECH SKILLS, *AURALLY HANDICAPPED, SENSORY EXPERIENCES, *AUDITORY VISUAL TESTS, AUDITORY PERCEPTION, VISUAL PERCEPTION, LEARNING EXPERIENCES, HANDICAPPED CHILDREN, NORMAN OKLAHOMA

VISUAL AND AUDITORY CUES WERE TESTED, SEPARATELY AND JOINTLY, TO DETERMINE THE DEGREE OF THEIR CONTRIBUTION TO IMPROVING OVERALL SPEECH SKILLS OF THE AURALLY HANDICAPPED. EIGHT SOUND INTENSITY LEVELS (FROM 6 TO 15 DECIBELS) WERE USED IN PRESENTING PHONETICALLY BALANCED WORD LISTS AND MULTIPLE-CHOICE INTELLIGIBILITY LISTS TO A SAMPLE OF 24 SUBJECTS. THE SUBJECTS WERE DIVIDED EQUALLY INTO THREE GROUPS--(1) THOSE WITH NORMAL HEARING, (2) THOSE WITH RELATIVELY "FLAT" HEARING LOSS, AND (3) THOSE WITH "DROPPING" OR "SLOPING" HEARING LOSS. SCORES, CONSISTING OF THE NUMBER OF CORRECT RESPONSES, WERE OBTAINED WITH AUDITORY AND VISUAL CUES, ALONE AND THROUGH AN INTERACTION OF BOTH AS A FUNCTION OF DISCRETE INTENSITY INCREASE. ANALYSIS OF THE VARIOUS EFFECTS AND INTERACTIONS WAS CONDUCTED THROUGH THE USE OF VARIANCE TECHNIQUES. THE ABILITY TO INTERPRET CORRECTLY SPOKEN LANGUAGE WITH THE BISENSORY APPROACH GREATLY EXCEEDED THAT YIELDED BY EITHER AUDITION OR VISION IN ISOLATION. FUTURE ATTEMPTS TO REHABILITATE AN INDIVIDUAL WHOSE HEARING IS IMPAIRED THROUGH LIPREADING INSTRUCTION AND AUDITORY TRAINING SHOULD THUS COMBINE THESE TWO TYPES OF TRAINING INTO A UNIFIED INSTRUCTIONAL PROGRAM. (JH)

ED 002887

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
Office of Education
This document has been reproduced exactly as received from the person or organization originating it. Points of view or opinions stated do not necessarily represent official Office of Education position or policy.

EFFECTS AND INTERACTIONS OF AUDITORY AND VISUAL CUES IN ORAL COMMUNICATION*

Submitted to

The Office of Education
Department of Health, Education,
and Welfare

As a Final Report
of
Project #499
Contract SAE 8177

By

THE UNIVERSITY OF OKLAHOMA RESEARCH INSTITUTE

Project Director: John W. Keys, Ph. D.
Principal Investigator: Richard F. Krug, M. A.
Research Associate: Henry E. Spuehler, Ph. D.

*The research reported herein was performed pursuant to a contract with the United States Office of Education, Department of Health, Education, and Welfare.

3414a

ACKNOWLEDGEMENTS

The project director and the University of Oklahoma Research Institute take this opportunity to acknowledge the efforts of Dr. Tom W. Tillman and Mr. Dean A. Harris of the University of Oklahoma Speech and Hearing Clinic, in connection with this project. Dr. Tillman offered a great deal of assistance in the tabular and graphic analysis of the data reported herein. In addition, he was almost entirely responsible for preparing the final manuscript. Mr. Harris prepared the various graphs for reproduction.

TABLE OF CONTENTS

	Page
LIST OF TABLES	iv
LIST OF FIGURES	v
INTRODUCTION	1
APPARATUS	3
SUBJECTS	4
PROCEDURES	8
RESULTS	12
CONCLUSIONS	26
REFERENCES	29

LIST OF TABLES

Table | Page

1. Mean number and percent of words from PB lists reproduced correctly by three groups of subjects under three conditions of presentation (Visual, Auditory, Bisensory) 15

2. Mean number and percent of words from Black lists reproduced correctly by three groups of subjects under three conditions of presentation (Visual, Auditory, Bisensory) 23

3. Summary of analysis of variance 25

LIST OF FIGURES

Figure — Page

1. Mean hearing levels in DB Re: USPHS Norm for Group II and Group III 6

2. Mean visual, auditory, and bisensory discrimination scores for three groups using PB word lists 14

3. Comparison of bisensory performance with arithmetic sum of auditory and visual performances for three groups using PB word lists 20

4. Mean visual, auditory and bisensory discrimination scores for three groups using Black lists 22

5. Comparison of bisensory performance with sum of auditory and visual performances for three groups using Black lists 24

EFFECTS AND INTERACTIONS OF AUDITORY AND VISUAL CUES IN ORAL COMMUNICATION

Introduction

A great deal of effort has been expended in attempts to develop adequate means of measuring lip-reading skill, to relate it to other measureable aspects of behavior and to develop means of teaching this skill to individuals who have suffered auditory impairment (3, 7, 10, 12, 14-16, 19-21). Likewise, many workers have applied themselves to the task of developing means of testing auditory discrimination and to that of increasing the efficiency of the impaired auditory mechanism through training (2, 4, 5, 17, 22). By and large a dichotomy of effort has existed in these two areas of interest. That is to say, few investigators have viewed lip-reading ability and auditory discrimination simultaneously in an effort to determine the perhaps unique manner in which the two skills interact within the individual to produce a given level of communicatory efficiency.

The sparse evidence which is available suggests that most workers have concerned themselves with the individual's ability to understand spoken language when auditory cues alone were available to him as opposed to that which he achieved under bisensory stimulation, i. e., when auditory and visual cues were presented simultaneously (6, 11, 13, 18). In short, these workers either did not assess visual functioning alone or else failed to take the precautions necessary to assure that under the condition in which only visual cues were to be presented no auditory signal was available to the observer. Hutton (8) assessed the hearing impaired individual's efficiency in interpreting speech when only its visual or its auditory cues were available to him. In addition, he assessed this communicatory efficiency under a condition in which both the auditory and visual cues of speech

were presented simultaneously. It should be pointed out here that Hutton did not attempt to control such parameters as degree of hearing impairment, audiometric configuration, age at onset, and relative intensity of the auditory stimulus.

Hutton concluded that in terms of consonant recognition the hypacousic subjects whom he studied received approximately 50% more information from auditory stimuli than from visual stimuli. He also reported that the information transmitted under the bisensory condition exceeded that transmitted by the auditory cues alone but was considerably less than the arithmetic sum of the information transmitted by the visual and auditory avenues in isolation. This conclusion was similar to that of O'Neill (13) who studied only normal hearing subjects. O'Neill did not, however, assess visual function in isolation from auditory function.

It seems clear that those concerned with the education and rehabilitation of the acoustically handicapped have little information available by which to assess the relative contribution to the reception of speech made by auditory cues as opposed to visual cues. There is even less evidence to indicate what to expect from the given individual in terms of his efficiency in discriminating speech when both visual and auditory cues are presented simultaneously. Should the speech or hearing clinician then attempt to impart lip-reading skill in isolation from her attempts at auditory training or are these two tasks more easily and efficiently accomplished simultaneously?

The present study is an attempt to isolate the contributions of visual and auditory cues to the understanding of speech. In addition it represents an attempt to assess the effects of the interaction of these two types of stimuli on the understanding of speech presented through bisensory channels, i. e., vision and audition simultaneously. The experimental problem was to

to determine whether the interaction between visual and auditory cues produced a different level of performance in the impaired ear as opposed to the normal ear. In addition, it was thought that comparison of the data for the two hearing impaired groups, which differed only in terms of audiometric configuration, would permit conclusions relative to the effect of type of audiometric configuration on the level of performance produced by the bisensory interaction under consideration.

Figure 2 displays the results obtained for the three groups under the various experimental conditions utilizing the PB word lists. The data from which the various curves in this figure were plotted are contained in Table 1.

Before considering the data displayed in Figure 2, some explanation of the manner in which the various curves were derived is in order. The curves for visual performance appear as straight lines near the bottom of the figure. It will be recalled that a visual discrimination score was obtained only once for each subject. However, eight points are shown in order to make visual comparison of the three conditions easier. All 24 subjects were tested visually using the same word list. It would appear that this action would require the assumption that all seventeen word lists employed were equivalent in terms of visual difficulty. Such an assumption would, in all probability, be invalid. However, even assuming that all lists were <u>not</u> equivalent in terms of visual difficulty, it would seem reasonable to make the assumption that even though a particular list may have been more or less difficult than any other list the relative difficulty for a given list would remain constant both within and between groups. The upper curves in this figure labeled auditory and bisensory were plotted from data obtained with the intensity of the auditory cue

MX-41/AR cushions and held in a standard headband. The acoustic output of this instrument was calibrated by means of an audiometer calibrating unit (Allison, Model 3A).

The experimental apparatus used to present the speech stimuli in the auditory and bisensory conditions was a custom built speech audiometer feeding a single earphone (Telephonics, Type 39-10Z) mounted in an MX-41/AR cushion. This earphone was held in a standard headband opposite a dummy earphone which was also mounted in an MX-41/AR cushion. Measurements made prior to the experiment demonstrated that the speech audiometer equalled or exceeded all specifications listed in the American Standards Specifications for Speech Audiometers (1) with one exception. The Specification lists 22 db (SPL referred to 0.0002 microbar in an ASA type-1 coupler) as the norm for speech. The output of the speech audiometer employed in this study was adjusted to produce 29 db SPL re: 0.0002 microbar with the hearing level of the audiometer set to zero. This adjustment was made in order to obtain the 13 db relationship between the pure tone and speech audiometric norms which has been suggested by Jerger and others (9) as the proper relationship to be specified for audiometric standards.

Subjects

Three experimental groups of eight subjects each were utilized in this investigation. One group, hereafter referred to as Group I, consisted of normal hearing subjects. A second group, hereafter referred to as Group II, was composed of hearing impaired subjects whose audiometric configurations were relatively flat through the frequency range 500 to 2000 cps. A third group, Group III, contained hearing impaired subjects whose audiometric configurations sloped gradually in the frequency range from 500 to 2000 cps.

Certain of the subject selection criteria were common to all groups. That is, all subjects were adults who used spoken language as their primary tool of communication and who had acquired speech and language through the auditory avenue. In order to insure that the visual acuity of each subject was sufficient to allow him to observe the experimenter accurately at a distance of eight feet, the visual acuity of each subject was screened by means of a standard Snellen Eye Chart. The subject selection criteria which were unique to a given group are discussed below.

Group I (Normal Hearing). All prospective subjects for this group were screened audiometrically at a hearing level (hearing loss dial setting) of 20 db, reference USPHS norm, at each octave interval from 125 to 8000 cps. No subject was accepted who failed to respond to any test frequency at the screening intensity in either ear. The eight subjects subsequently selected for this group included two males and six females ranging in age from 22 to 34 years with a mean age of 31.5 years. Only one ear of each subject was utilized in the collection of the data reported below.

Group II (Flat Audiometric Configuration). The files of the University of Oklahoma Speech and Hearing Clinic served as a source of potential subjects for this group. In order to be included in this group a subject was required to display a moderate bilateral loss of hearing acuity and a relatively flat audiometric configuration within the frequency range from 500 to 2000 cps. Specifically, an average pure tone loss from 500 to 2000 of at least 30 db was required, and the maximum allowable average loss in the same range was 65 db. No subject was included in this experimental group whose audiogram revealed differences in hearing level greater than 10 db between adjacent octaves from 500 to 2000 cps. Figure 1 shows the mean hearing levels at the various test frequencies for the eight subjects in this group.

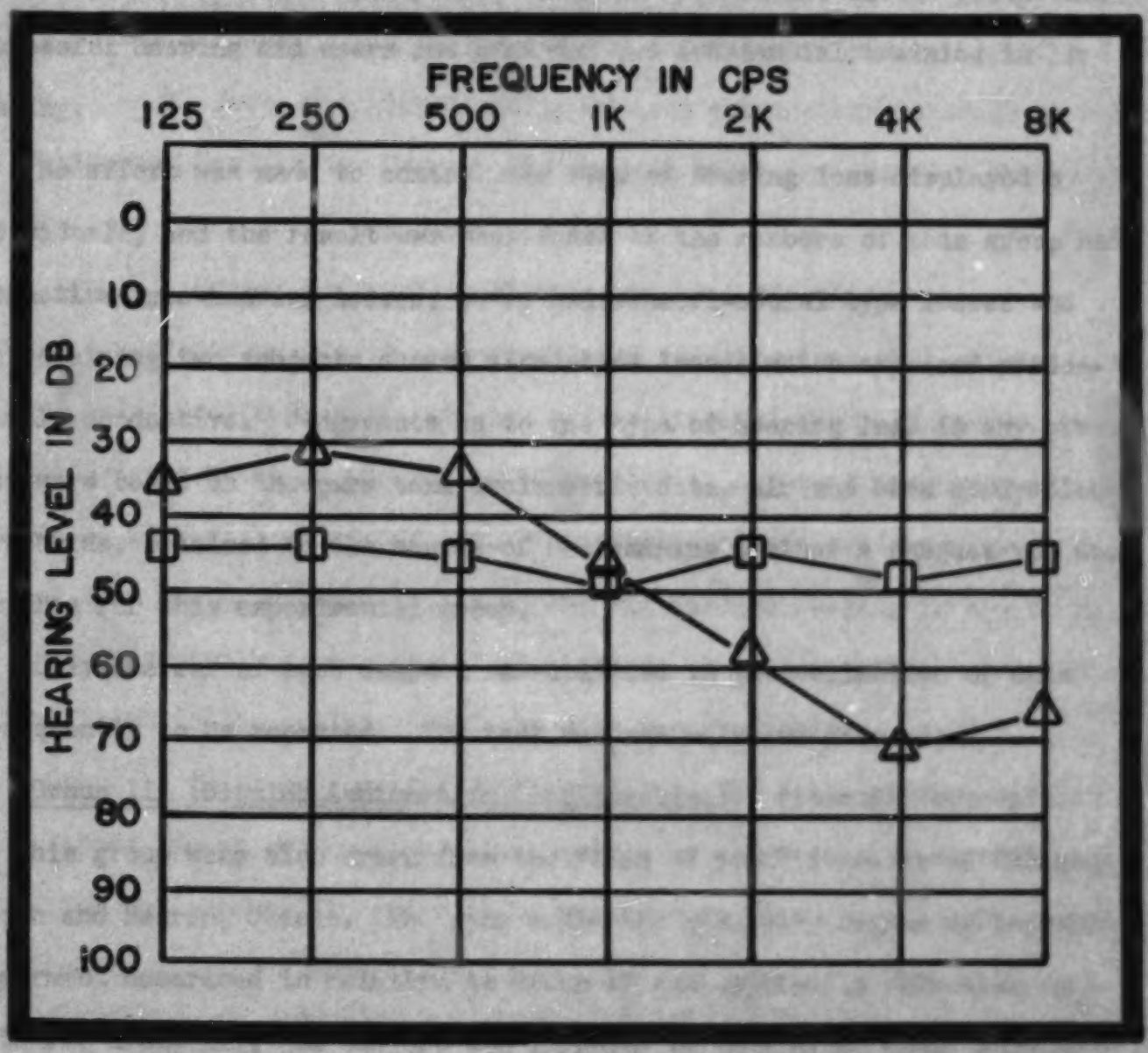


FIGURE 1. MEAN HEARING LEVELS IN DB RE: USPHS NORM FOR GROUP II (□) AND GROUP III (△).

The subjects eventually selected for this group were all females ranging in age from 36 to 69 years with a mean age of 46.6 years. The duration of hearing loss for the individuals in the group ranged from 10 to 50 years with a mean duration of 23.9 years. Four of the members of the group were successful hearing aid users and none had had substantial training in lip reading.

No effort was made to control the type of hearing loss displayed by individuals, and the result was that three of the members of this group had conductive-type hearing losses, three had sensori-neural type losses and the remaining two subjects showed mixed-type losses which appeared predominantly conductive. Judgements as to the type of hearing loss in any given case were based on the pure tone audiometric data, air and bone conduction thresholds, obtained in the course of determining whether a subject met the criteria for this experimental group.

Only one ear of each subject was utilized in the collection of data subsequently to be reported. The test ear was selected at random.

Group III (Sloping Audiometric Configuration). Potential subjects for this group were also drawn from the files of the University of Oklahoma Speech and Hearing Clinic. The same criterion regarding degree of hearing impairment described in relation to Group II was applied in selecting subjects for Group III. No subject was included in this group whose audiometric configuration revealed less than a 15-db slope from 500 to 2000 cps. That is, it was required that the hearing level at 2000 cps exceed that at 500 cps by a minimum of 15 db. Figure 1 shows the mean audiometric configuration for this group.

Of the eight subjects ultimately selected for this group, four were

females and the remainder males. These eight subjects ranged in age from 26 to 58 years with a mean age of 46 years. The duration of individual hearing losses ranged from two to 40 years with a mean duration of 15.8 years. Only two members of this group were successful hearing aid users and none had had previous lip-reading training.

As in Group II, no attempt was made to control type of hearing loss. Seven of the eight subjects in this group were classified as having sensori-neural type hearing losses and the eighth individual displayed a mixed-type loss which appeared predominantly sensori-neural. As in Group II, these classifications were made on the basis of the preliminary pure tone audiometric data gathered to insure that each subject met the criteria specified for assignment to this experimental group.

Only one ear of each subject was utilized in the collection of the experimental data and assuming that both ears of each subject met the above criteria, the test ear was chosen randomly.

Procedures

Preliminary. Each of the 24 subjects in this study was seen in a single experimental session. The first portion of each session was devoted to routine pure tone audiometry necessary for the collection of data required to insure that each subject met the pertinent criteria described earlier. As previously stated, each of the normal hearing subjects was audiometrically screened at a hearing level of 20 db. Pure tone audiograms by both air and bone conduction were recorded for each of the subjects in Groups II and III. The pure tone thresholds were recorded using a descending "clinical" method of measurement and 5-db steps. Threshold was defined as the lowest hearing level at which the subject

responded to at least two out of three tonal presentations. This procedure was followed for both air and bone conduction testing.

Experimental. Following the preliminary test procedures, the threshold of hearing for spondee words was recorded for the test ear of each experimental subject. This threshold was later to serve as a reference for adjusting the intensity level of the auditory signal presented under the auditory and the bisensory experimental conditions. Spondee thresholds were recorded in the following manner. A monitored live-voice procedure was employed in which the initial spondee word was presented at an intensity level approximately 15 db above the individual subject's average pure tone loss from 500 to 2000 cps. In the case of the normal hearing subjects, for whom pure tone thresholds were not recorded, the initial spondee word was presented at a hearing level of 15 db, i. e., a hearing loss dial setting of 15 db on the speech audiometer. Following a correct response to the initial test word, the intensity of the speech signal was attenuated by 2 db and a second word was presented. The experimenter continued to descend in 2-db steps, presenting just one word per step, until the subject either failed to respond or responded incorrectly. The intensity of the signal was left at this level and eight to 10 more words were presented. The experimenter's subsequent activity was dictated by the subject's responses to these words. If more than 50% of the words were identified correctly he descended in 1-db steps until a level was reached at which the subject correctly repeated 50% of a sample of six to 10 words. If fewer than 50% of these words were repeated correctly the experimenter increased the intensity of the speech signal by 4 db and presented six to 10 words. If more than 50% of the words were repeated

correctly at this level, he then descended in 1-db steps, presenting six to 10 words per step, until a level was reached at which a 50% correct response was recorded. In short, the experimenter sought the level at which a 50% correct response was obtained and defined this level as threshold. In the event that more than 50% of the words were repeated at one level and less than 50% were repeated at a level 1 db lower, then threshold was defined as the higher of the two levels.

Following the recording of the spondee threshold, 17 different discrimination scores were obtained for each of the two different types of speech material. One of these was represented by lists, one through 17 of the Harvard Psychoacoustics Laboratory Phonetically Balanced (PB) Word Lists (5). The second type was represented by 17 lists selected from forms C and D of the multiple-choice intelligibility lists developed by Black (2). These 17 presentations were divided into three separate conditions (a) visual; (b) auditory; (c) bisensory. The discrimination score in any given instance took the form of a percent correct response of the total number of words on any given list. Each PB list contained 50 items, each valued at 2%, while each Black List contained 27 items, each of which carried a weight of approximately 3.7%.

Under the visual condition, the test items were presented to the subject in such a way that the only cues available to him were those he received by viewing the experimenter as he spoke the items. This was accomplished by seating the subject in front of a 15 by 38 inch window situated in the wall between the control room and the test chamber. This was a three-paned sound-proofed window which effectively attenuated auditory stimuli, but which allowed unobstructed observation. A 100 watt

lamp was situated so as to reflect light off the wall in front of the experimenter to eliminate the slight shadow cast by the overhead lighting. Under this visual condition the same PB list and the same Black list was presented to each of the 24 subjects. The percent correct response from this presentation was used as a measure of the individual's efficiency in the visual reception of speech.

Under the auditory condition, eight different discrimination scores were recorded by means of the monitored live-voice technique for each type of word list. The eight scores were obtained with the intensity of the speech stimulus adjusted to each of eight different sensation levels. These levels were -6 db, -3 db, 0 db, 3 db, 6 db, 9 db, 12 db and 15 db (re: individual subject's spondee threshold). The scores obtained under this condition in which only auditory cues were available to the subject allowed an evaluation of the subject's efficiency in the auditory reception of speech as a function of sensation level.

The third condition, the bisensory condition, also yielded eight different discrimination scores for each type of word list. These scores were obtained under a condition in which the subject was again allowed to view the experimenter as he spoke the items. However, in addition, the auditory stimulus was also provided, again utilizing the monitored live-voice technique, at the same eight sensation levels used under the auditory condition. The scores obtained here yielded an estimate of the subject's efficiency in the bisensory reception of speech as a function of the sensation level of the auditory stimulus.

As stated earlier, the same PB list and the same Black list were

utilised for all subjects under the visual condition. However, for the 16 presentations of each type of list under the conditions, auditory and bisensory, in which the auditory cue was made available, the remaining 16 lists of each type were randomised over sensation level. In addition, the total of 32 tests administered to each subject were presented in a separate random order for each of the 24 subjects in this design. This procedure was utilised in order to minimise any systematic order effect or list effect.

As stated earlier, each subject was seen in a single experimental session. The length of the sessions varied from two hours and fifteen minutes to three hours. Appropriate rest periods were interspersed throughout the test session in an attempt to avoid spurious results due to fatigue.

Results

The experimental design described above was evolved in order to assess the relative contribution of visual and auditory cues to the efficiency of the individual in receiving oral communication. In addition, the design allowed some evaluation of the manner in which these two types of cues interact when the individual receives oral communication by means of visual and auditory avenues simultaneously. Two types of speech stimuli were utilised in order to determine whether differences in the processes described above exist for different types of speech samples. Data were gathered under several conditions in which the relative intensity of the auditory signal was varied. This portion of the design was included to determine whether the interaction between visual and auditory cues served to produce differences in level of performance as the intensity of the auditory portion of the bisensory signal was varied. Lastly, three groups of subjects, differing in level of hearing acuity and type of audiometric configuration, were studied. These three groups were studied in order

to determine whether the interaction between visual and auditory cues produced a different level of performance in the impaired ear as opposed to the normal ear. In addition, it was thought that comparison of the data for the two hearing impaired groups, which differed only in terms of audiometric configuration, would permit conclusions relative to the effect of type of audiometric configuration on the level of performance produced by the bisensory interaction under consideration.

Figure 2 displays the results obtained for the three groups under the various experimental conditions utilizing the PB word lists. The data from which the various curves in this figure were plotted are contained in Table 1.

Before considering the data displayed in Figure 2, some explanation of the manner in which the various curves were derived is in order. The curves for visual performance appear as straight lines near the bottom of the figure. It will be recalled that a visual discrimination score was obtained only once for each subject. However, eight points are shown in order to make visual comparison of the three conditions easier. All 24 subjects were tested visually using the same word list. It would appear that this action would require the assumption that all seventeen word lists employed were equivalent in terms of visual difficulty. Such an assumption would, in all probability, be invalid. However, even assuming that all lists were <u>not</u> equivalent in terms of visual difficulty, it would seem reasonable to make the assumption that even though a particular list may have been more or less difficult than any other list the relative difficulty for a given list would remain constant both within and between groups. The upper curves in this figure labeled auditory and bisensory were plotted from data obtained with the intensity of the auditory cue

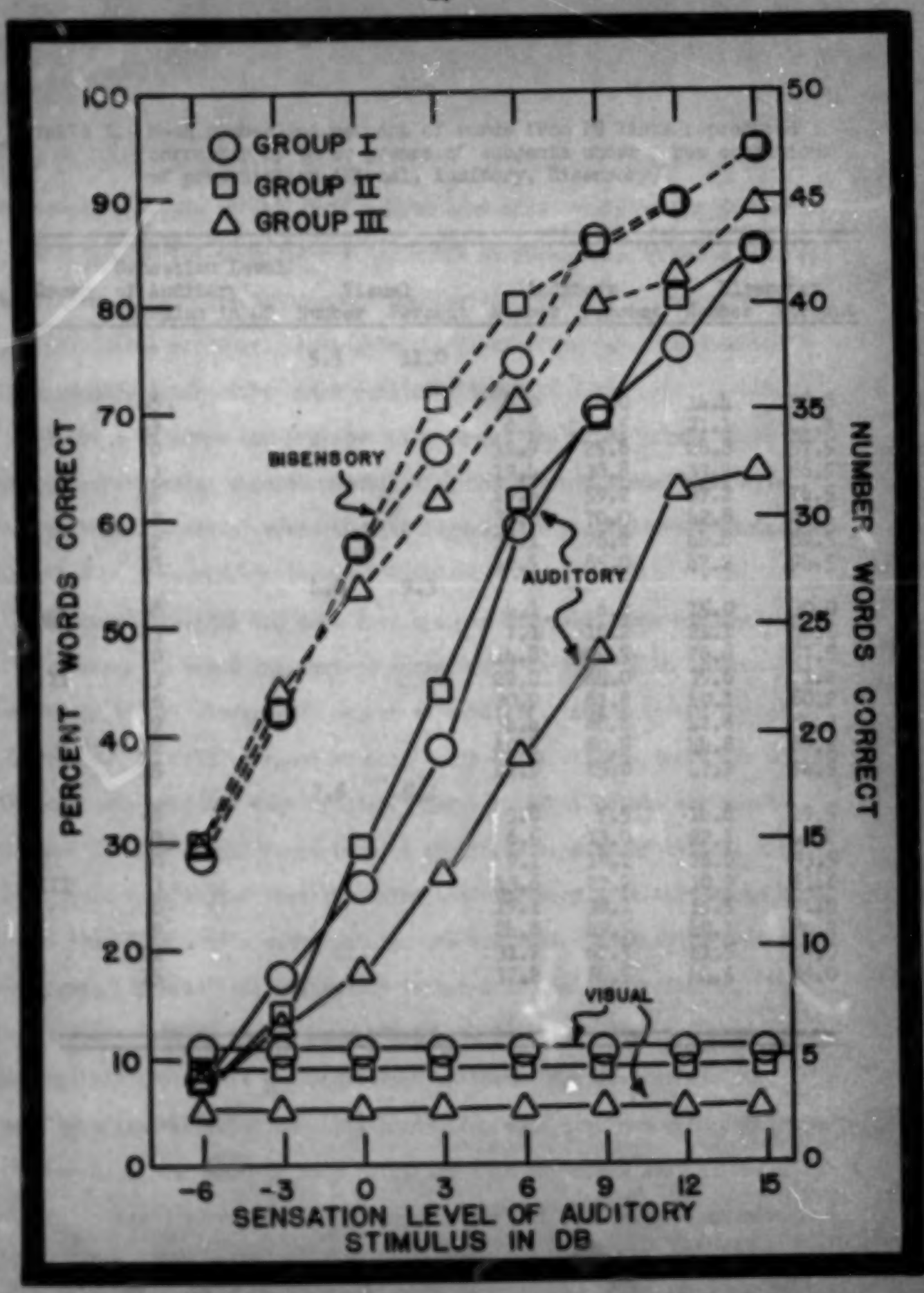


FIGURE 2. MEAN VISUAL, AUDITORY AND BISENSORY DISCRIMINATION SCORES FOR THREE GROUPS USING PB WORD LISTS.

Table 1. Mean number and percent of words from PB lists reproduced correctly by three groups of subjects under three conditions of presentation (Visual, Auditory, Bisensory).

Group	Sensation Level of Auditory Stimulus in DB	Visual Number	Visual Percent	Auditory Number	Auditory Percent	Bisensory Number	Bisensory Percent
		5.5	11.0				
	-6			4.0	8.0	14.4	28.8
	-3			8.8	17.5	21.1	42.3
	0			12.9	25.8	28.8	57.5
I	3			19.4	38.8	33.2	66.5
	6			29.6	59.2	37.2	74.5
	9			35.0	70.0	42.8	85.5
	12			38.1	76.2	44.8	89.5
	15			42.5	85.0	47.2	94.5
		4.6	9.3				
	-6			4.1	8.2	15.0	30.0
	-3			7.1	14.2	21.1	42.2
	0			14.8	29.5	28.8	57.5
II	3			22.0	44.0	35.6	71.2
	6			30.9	61.8	40.1	80.2
	9			34.4	68.8	42.6	85.2
	12			40.2	80.5	44.8	89.5
	15			42.5	85.0	47.2	94.5
		2.6	5.3				
	-6			3.8	7.5	14.8	29.5
	-3			6.5	13.0	22.1	44.2
	0			9.1	18.2	26.8	53.5
III	3			13.6	27.2	30.9	61.8
	6			19.1	38.2	35.5	71.0
	9			24.8	49.5	40.1	80.2
	12			31.2	62.5	41.5	83.0
	15			32.2	64.5	44.5	89.0

adjusted to each of eight different sensation levels. These six curves therefore represent psychometric functions in which the percent correct response is plotted relative to the sensation level of the auditory signal.

Inspection of Figure 2 reveals several important factors. First, while Groups I and II yielded essentially equivalent scores in terms of visual performance, Group III deviated from the other two groups in the direction of a poorer level of visual performance. This finding would tend to indicate that sampling error was not avoided in the selection of the subjects for Group III. Such an occurrence was not unexpected since all subjects in both impaired groups were selected from the clinical files of the University of Oklahoma Speech and Hearing Clinic. It will be recalled that these two groups differed in terms of the shape of their audiometric configurations. It will be recalled that the configuration of Group II was relatively flat and that of Group III sloping (See Figure 1). The flat configuration of Group II, combined with the fact that the majority of the members of this group had primarily conductive-type hearing losses would tend to suggest that these individuals should display excellent auditory discrimination. These individuals could be classified potentially excellent hearing aid users. Individuals falling within this classification do not ordinarily seek the services of a hearing clinic for the selection of a hearing aid. A substantial number of the members of this group were, in fact, referred to the hearing clinic for routine audiometric tests because they were being considered as candidates for some form of middle ear surgery.

Considering Group III, however, the sloping configurations combined with the fact that the majority of this group had sensori-neural type hearing losses would point toward reduced auditory discrimination. In

this group are found the "problem cases" insofar as clinical evaluation and selection of hearing aids are concerned. A greater percentage of this group of hearing impaired individuals eventually finds its way to the hearing clinic for help in hearing aid selection than is true in the case of that portion of the hearing impaired population represented by Group II. It is not at all inconceivable that those persons with impaired auditory discrimination who eventually seek the aid of the hearing clinic should be those who display some impairment in lip-reading skill. In other words, these individuals seek the aid of a hearing clinic not only because they obtain less than optimum help from hearing aid use, but probably also because they experience difficulty in their attempts to pick up additional information through the visual avenue. It is believed to be these factors which ultimately produced the apparent sampling error in the selection of subjects for Group III.

Further study of Figure 2 reveals that the auditory articulation functions for Groups I and II are essentially superimposed. These functions reveal that the percent correct response for these groups is monotonically related to sensation level. That is, as sensation level is increased from -6 db to +15 db the percent correct response shows a corresponding increase. It seems reasonable to assume that these curves would have continued to rise, had tests been administered at sensation levels higher than +15 db, until they reached a plateau near 100% correct response. This plateau would undoubtedly have been maintained as the intensity of the auditory signal was increased to even higher levels.

Inspection of the auditory articulation function for Group III reveals that the performance of this group deviated markedly from that of the other two groups. This deviation is apparent in two respects. First, although

the performance of the three groups is essentially equivalent at the lowest two sensation levels, the articulation curve for Group III breaks away from those of the other two groups at a sensation level of 0 db. The deviation of the curve for Group III becomes more and more pronounced as the sensation level of the auditory signal is increased. In other words, the articulation function for Group III is much less steep than those of Groups I and II. Secondly, the articulation function for Group III appears to reach a maximum at a sensation level of +15 db. At this level the group yielded a mean auditory discrimination score of only 64.5% as opposed to mean scores of 85% for the other two groups at the same sensation level. Had higher sensation levels been explored with Group III this maximum discrimination score would probably not have increased to any substantial degree and it is conceivable that the articulation function may have bent back upon itself. That is, it is possible that scores of less than 64.5% may have resulted.

It is clear, then, that the level of efficiency in receiving oral communication is considerably lower for Group III as compared with Groups I and II when either the visual or the auditory avenue is considered in isolation. Inspection of the bisensory articulation functions in Figure 2, however, reveals a somewhat different picture. Although the mean bisensory performance of Group III begins to fall below that of the other two groups at a sensation level of 0 db, and this tendency continues as sensation level is increased, this difference in the bisensory performance of Group III is much less marked at all sensation levels than that observed when auditory performance was considered in isolation. Had visual performance not been assessed in isolation, the logical conclusion might have been that the individuals in Group III were simply better lip readers than those in the other two groups. However, just the opposite condition was actually

observed. That is, the mean visual performance of Group III was actually poorer than the mean visual performance of the other two groups. It seems reasonable to conclude, therefore, that the interaction between the visual and auditory cues when they were presented simultaneously acted to produce a markedly higher relative performance level for Group III than for Groups I and II. In fact, the absolute bisensory performance level for Group III approached fairly closely those of the other two groups. (See Figure 2).

After assessing visual and auditory discrimination for speech in isolation from each other, it is logical to ask whether bisensory discrimination for the same type of speech sample is a simple arithmetic sum of the two. The data displayed in Figure 3 demonstrate rather convincingly that such is not the case when the speech sample is made up of PB word lists. The points on each of the curves in Figure 3 were derived by subtracting the arithmetic sum of the auditory and visual scores from the bisensory discrimination score. Thus, a positive value indicates that the latter score exceeded the arithmetic sum of the auditory and visual scores and vice versa. It can be seen that the bisensory score exceeded the sum of the visual and auditory scores at every sensation level for all three groups with two exceptions. At a sensation level of 12 db the bisensory score for Group II was exceeded by the auditoty-visual sum. The same is true at a sensation level of 15 db for Group I. However, in both instances the bisensory score was exceeded by a relatively small margin.

Further inspection of Figure 3 reveals that the difference score curves for Groups I and II interweave throughout the range of sensation levels studied indicating that these two groups achieved essentially equivalent performance as a function of sensation level. However, the curve for Group III clearly deviates from those of the other two groups at every sensation

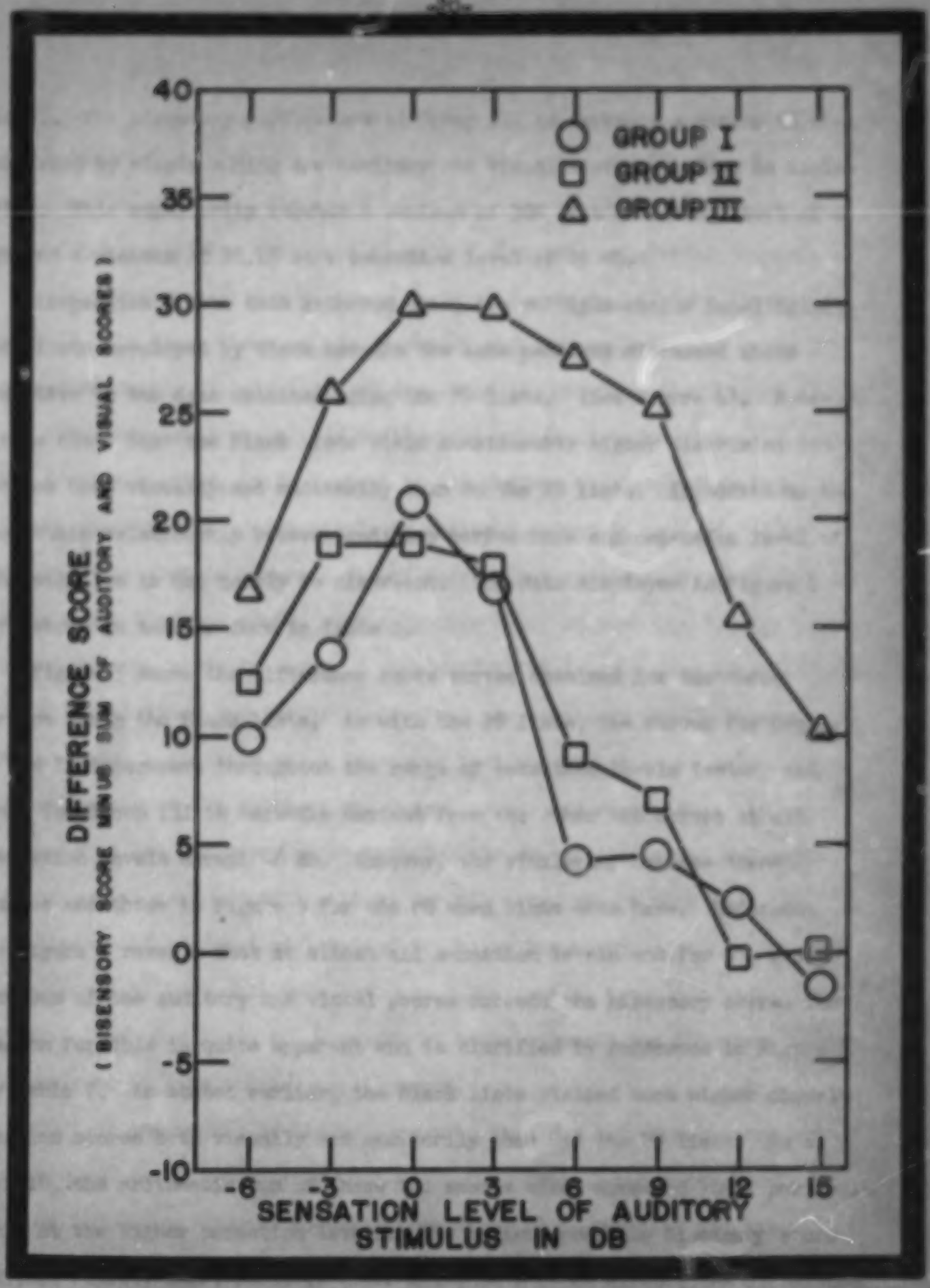


FIGURE 3. COMPARISON OF BISENSORY PERFORMANCE WITH ARITHMETIC SUM OF AUDITORY AND VISUAL PERFORMANCES FOR THREE GROUPS USING PB WORD LISTS.

level. The bisensory performance of Group III is markedly superior to that achieved by simply adding the auditory and visual scores obtained in isolation. This superiority reaches a maximum of 30% at a sensation level of 0 db and a minimum of 20.2% at a sensation level of 15 db.

Inspection of the data gathered using the multiple-choice intelligibility lists developed by Black reveals the same patterns discussed above relative to the data obtained using the PB lists. (See Figure 4). However, it is clear that the Black lists yield considerably higher discrimination scores both visually and auditorily than do the PB lists. In addition, the monotonic relationship between auditory performance and sensation level of the stimulus is not nearly so clear-cut. The data displayed in Figure 4 are shown in tabular form in Table 2.

Figure 5 shows the difference score curves obtained for the three groups using the Black lists. As with the PB lists, the curves for Groups I and II interweave throughout the range of sensation levels tested, and that for Group III is markedly deviant from the other two curves at all sensation levels except -6 db. However, the similarity between these curves and those in Figure 3 for the PB word lists ends here. Reference to Figure 5 reveals that at almost all sensation levels and for all groups the sum of the auditory and visual scores exceeds the bisensory score. The reason for this is quite apparent and is clarified by reference to Figure 4 or Table 2. As stated earlier, the Black lists yielded much higher discrimination scores both visually and auditorily than did the PB lists. As a result, the arithmetic sum of these two scores often exceeded 100%, particularly at the higher sensation levels. The maximum possible bisensory score was, of course, 100%, so it is clear that, to a large extent, the difference scores plotted in Figure 5 are artifacts of this particular circumstance.

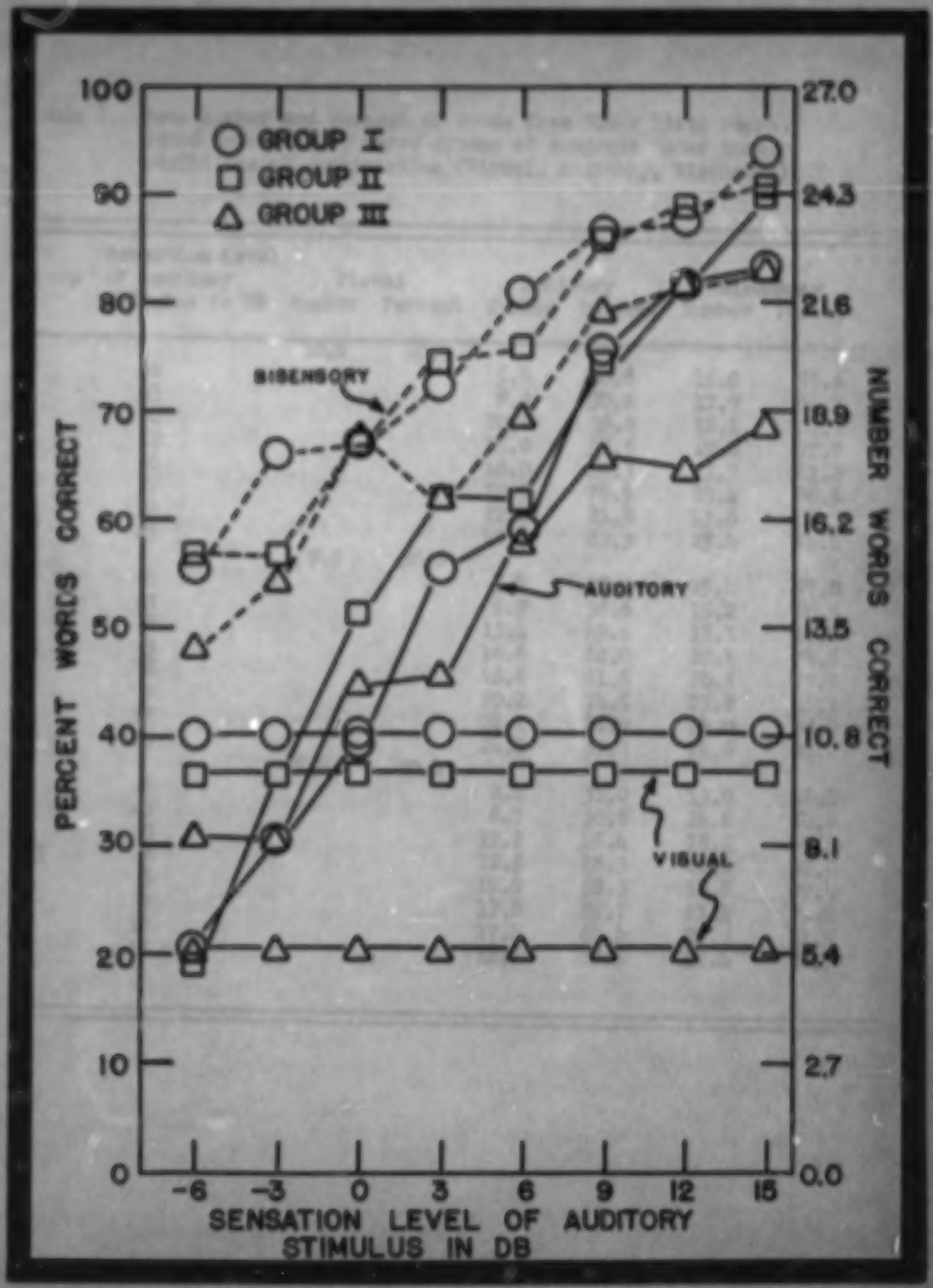
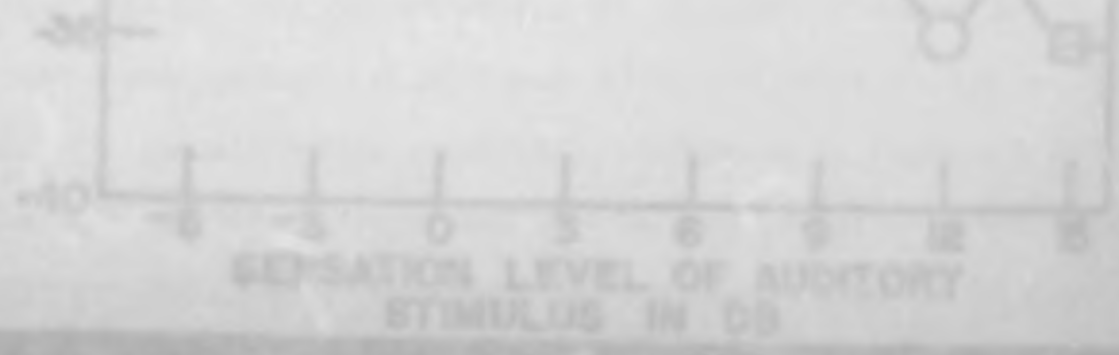


FIGURE 4. MEAN VISUAL, AUDITORY AND BISENSORY DISCRIMINATION SCORES FOR THREE GROUPS USING BLACK LISTS.

Table 2. Mean number and percent of words from Black lists reproduced correctly by three groups of subjects under three conditions of presentation (Visual, Auditory, Bisensory)

Group	Sensation Level of Auditory Stimulus in DB	Visual		Auditory		Bisensory	
		Number	Percent	Number	Percent	Number	Percent
		10.9	40.3				
I	-6			5.6	20.8	15.0	55.6
	-3			8.2	30.6	17.9	66.2
	0			10.8	39.8	18.1	67.1
	3			15.0	55.6	19.6	72.7
	6			16.0	59.3	21.9	81.0
	9			20.5	75.9	23.4	86.6
	12			22.1	81.9	23.6	87.5
	15			22.5	83.3	25.4	94.0
		9.9	36.6				
II	-6			5.1	19.0	15.4	57.0
	-3			9.9	36.6	15.2	56.5
	0			13.4	49.6	18.1	67.1
	3			16.8	62.0	20.1	74.5
	6			16.6	61.6	20.5	75.9
	9			20.1	74.5	23.2	86.1
	12			22.1	81.9	24.0	88.9
	15			24.2	89.8	24.6	91.2
		5.5	20.4				
III	-6			8.4	31.0	13.0	48.2
	-3			8.2	30.6	14.6	54.2
	0			12.2	45.4	18.2	67.6
	3			12.5	46.3	16.8	62.0
	6			15.8	58.3	18.8	69.4
	9			17.8	65.7	21.4	79.2
	12			17.4	64.4	22.0	81.5
	15			18.5	68.5	22.4	82.9



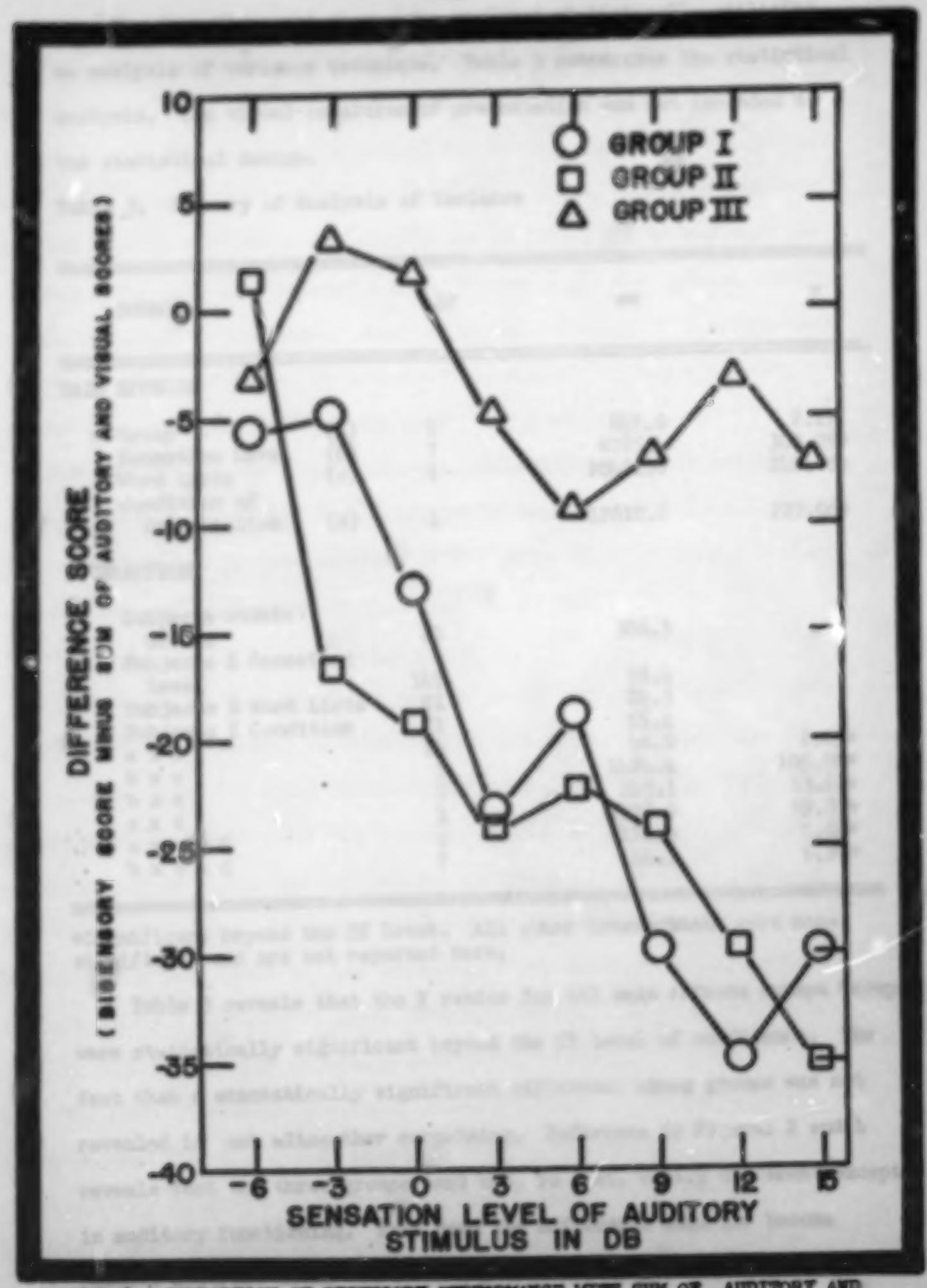


FIGURE 5. COMPARISON OF BISENSORY PERFORMANCE WITH SUM OF AUDITORY AND VISUAL PERFORMANCES FOR THREE GROUPS USING BLACK LISTS.

The data discussed above were analysed statistically utilising an analysis of variance technique. Table 3 summarises the statistical analysis. The visual condition of presentation was not included in the statistical design.

Table 3. Summary of Analysis of Variance

SOURCE		df	ms	F
MAIN EFFECTS				
Group	(a)	2	847.0	2.19
Sensation Level	(b)	7	6785.4	303.05*
Word Lists	(c)	1	20481.0	242.87*
Condition of Presentation	(d)	1	12610.0	229.06*
INTERACTIONS				
Subjects within Groups		21	386.3	
Subjects X Sensation Level		147	22.4	
Subjects X Word Lists		21	84.3	
Subjects X Condition		21	55.1	
a x b		14	46.0	2.05*
b x c		7	1424.4	105.50*
b x d		7	1[illegible]0.1	13.69*
c x d		1	2120.0	99.81*
a x c x d		2	124.0	5.84*
b x c x d		7	44.3	5.30*

*Significant beyond the 5% level. All other interactions were non-significant and are not reported here.

Table 3 reveals that the F ratios for all main effects except Groups were statistically significant beyond the 5% level of confidence. The fact that a statistically significant difference among groups was not revealed is not altogether surprising. Reference to Figures 2 and 4 reveals that the three groups were not, in fact, vastly different except in auditory functioning. Even here the difference does not become readily apparent until the intensity of the auditory signal reaches the 6-db sensation level.

Further interpretation of the statistical analysis must be made with caution due to the presence of three significant first order interactions and two significant second order interactions. Because of the significant interaction between the conditions of sensation level, method of presentation and type of word list, for example, it is impossible to say that any of these three main effects exerts a significant influence without specifying the particular circumstance under which the influence is exerted. That is, the effect of condition of presentation, auditory versus bisensory, depends upon sensation level of the auditory signal, etc.

Even in view of the indefinite conclusions allowed by the statistical analysis, inspection of the data displayed in Figures 2 through 5 leaves little doubt of the deviant behavior of the individuals in Group III when they are compared with those of the other two groups.

Conclusions

It is apparent from the data reported above that any attempt to assess an individual's efficiency in understanding the spoken language must take into consideration the total receptive mechanism. Attempts to arrive at an adequate assessment which are based on an evaluation of the relative contributions of vision and audition in isolation, seem grossly inadequate. This statement apparently holds true irrespective of the absolute hearing acuity of the individual and for both "flat" and "sloping" audiometric configurations. However, it seems particularly true for individuals who display this latter type of audiometric configuration.

The above statements are based on the findings of this experiment which suggest that for spoken language, such as the PB word lists, which is relatively difficult to interpret either visually or auditorily, the bisensory discrimination of the individual exceeds that which would be

predicted on the basis of the sum of his auditory and visual discrimination scores. For those individuals with good auditory discrimination at high intensity levels, this holds true only for sensation levels below which a 100% auditory discrimination score is achieved. For example, the mean difference between the bisensory discrimination score and the sum of the auditory and visual scores for Groups I and II tended to decrease as the PB words were presented at higher and higher sensation levels. In fact, at two of the higher sensation levels, 12 db for Group II and 15 db for Group I, the mean bisensory score was exceeded by the sum of the mean visual and auditory scores. This would appear to be due to the redundancy present in the bisensory signal. That is, on any given test item it may be possible to achieve a correct response by means of visual cues alone or, at the higher sensation levels, by means of the auditory cues alone. In such a circumstance, it is not possible for the interaction of these two cues in the bisensory condition to yield a higher performance than that yielded through either the auditory or visual avenues in isolation.

It should be pointed out that when speech material such as the Black lists are considered, the pattern of behavior described above is somewhat different. With such material which yields relatively high discrimination scores through either the visual or the auditory avenue, the redundancy factor becomes operative in the bisensory condition at relatively lower auditory signal levels with the result that the bisensory performance is usually exceeded by the sum of the auditory and visual performances.

The most important conclusion to be gleaned from the findings reported earlier, however, is as follows. For those individuals who display an impairment in auditory discrimination and visual discrimination, or lip-reading skill, the ability to interpret correctly spoken language through the bisensory avenue greatly exceeds that yielded by either audition or vision in isolation. Further, for such individuals (Group III) the

bisensory performance will usually exceed, by a substantial degree, that predicted on the basis of the arithmetic sum of the visual and auditory performance in isolation. This is particularly true if the speech sample under consideration is relatively difficult to interpret visually and auditorily. However, even with materials which are relatively easy to interpret, either visually or auditorily in isolation, these individuals yield bisensory performances which are only very slightly lower than the sum of the auditory and visual performances in isolation.

For those hearing impaired individuals whose auditory articulation function rises less steeply than normal and reaches a plateau at a level significantly below 100% correct response, the above statements apparently hold regardless of the intensity of the auditory signal. Since the majority of the hearing impaired population who seek the help offered by lip-reading instruction and auditory training probably fall in this group, these findings may have far reaching implications. That is, it seems reasonable to conclude that future attempts to rehabilitate the hearing impaired individual through lip-reading instruction and auditory training must combine the two types of training into a unified instructional program. Dealing with either of these areas in isolation would seem to be somewhat illogical since the person must function as a bisensory mechanism if he is to achieve his potential in interpreting oral communication. Therefore, to make the assumption that, by training audition and vision in isolation, the individual will be able to achieve a level of performance equal to that yielded by bisensory training, seems hazardous in view of the finding that the bisensory performance of these individuals is not a simple arithmetic sum of their visual and auditory performances measured in isolation.

References

1. American Standard Sound Measurement Package, American Standard Specifications for Speech Audiometers, appr. July 10, 1953. American Standards Association, Inc., 70 East 45th Street, New York 17, New York.

2. Black, J. W., Multiple-Choice Intelligibility Tests. J. Speech Hearing Dis., 22, 1957, 213-235.

3. Bunger, A. M., Speech Reading. Danville: Interstate Special Education Series, 1932.

4. Carhart, R. T., Auditory Training. In Hearing and Deafness. Ed. Hallowell Davis, New York: Murray Hill Book Co., 1947.

5. Egan, J. P., Articulation Testing Methods. Laryngoscope, 58, 1948, 955-991.

6. Ewing, A. W. G., Lipreading and Hearing Aids. Manchester: Manchester University Press, 1946.

7. Heider, G., Utley Lip Reading Test. Volta Rev., 49, 1947, 457-458.

8. Hutton, C., Combining Auditory and Visual Stimuli in Aural Rehabilitation. Volta Rev., 61, 1959, 316-319.

9. Jerger, J. F., Carhart, R. T., Tillman, T. W., and Peterson, J. L., Some Relations Between Normal Hearing for Pure Tones and for Speech, J. Speech Hearing Res., 2, 1959, 126-140.

10. Kitson, H. D., Psychological Tests for Lip-Reading Ability. Volta Rev., 17, 1915, 471-476.

11. Neely, K. K., Effects of Visual Factors on Intelligibility of Speech. J. acoust. Soc. Amer., 28, 1956, 1275-1277.

12. Nitchie, E. B., New Lessons in Lip Reading. Philadelphia: J. B. Lippincott Co., 1950.

13. O'Neill, J. J., Contributions of the Visual Components of Oral Symbols to Speech Comprehension. J. Speech Hearing Dis., 19, 1954, 429-439.

14. Pintner, R., Speech and Speech Reading Tests for the Deaf. Amer. Ann. Deaf, 74, 1929, 480-486.

15. Reid, G., A Preliminary Investigation in the Testing of Lip Reading Achievement. J. Speech Dis., 12, 1947, 77-82.

16. Reid, G., Problems in Testing. Volta Rev., 48, 1946, 660-661.

17. Streng, A., Fitch, W. J., Hedgecock, L. D., Phillips, J.W., and Carrell, J. A., Hearing Therapy for Children. New York: Grune and Stratton, 1955.

18. Sumby, W. H., and Pollach, I. J., Visual Contribution to Speech Intelligibility. J. acoust. Soc. Amer. 26, 1954, 212-215.

19. Utley, J., A Test of Lip Reading Ability. J. Speech Dis., 11, 1946, 109-116.

20. Utley, J., Factors Involved in the Teaching and Testing of Lip Reading Ability through the Use of Motion Pictures. Volta Rev., 48, 1946, 657-659

21. Vaughn, V. D., A Study of the Value of Certain Tests in Predicting Success in Speech Reading. Unpublished M. A. Thesis, Graduate College, The University of Oklahoma, 1954.

22. Whitehurst, M. W., and Monsees, E. K., Auditory Training for the Deaf. Washington, D. C.: The Volta Bureau, 1952.